SHORT REPORT

Instant Electronic Imaging Systems are Superior to Polaroid at Detecting Sight-threatening Diabetic Retinopathy

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Polaroid photography in diabetic retinopathy screening allows instant image availability to enhance the results of ophthalmoscopy. Retinal cameras are now being developed which use video/digital imaging techniques to produce an instant enlarged retinal image on a computer monitor screen. We aimed to compare one such electronic imaging system, attached to a Canon CR5 45NM, with standard Polaroid retinal photography. Two hundred and thirteen eyes from 107 diabetic patients were photographed through dilated pupils by both systems in random order and the images were analysed blind. Diabetic retinopathy was present in 58 eyes of which 55/58 (95 %) were detected on the electronic image and only 49/58 (84 %) on the Polaroid. Of 34 eyes requiring ophthalmologist referral according to standard European criteria, 34/34 (100 %) were detected on the electronic image and only 24/34 (71 %) on the Polaroid. Side by side comparisons showed electronic imaging to be superior to Polaroid at lesion detection. Using linear analogue scales, the patients assessed the electronic imaging photographic flash as less uncomfortable than the Polaroid equivalent ($p < 0.0001$). Other advantages of electronic imaging include: ready storage of the images with other patient clinical data on the diabetes computerized register/database; potential for image enhancement and analysis using image analysis software and electronic transfer of images to ophthalmologist or general practitioner. Electronic imaging systems represent a potential major advance for the improvement of diabetic retinopathy screening.

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Introduction

Combining the screening modalities of retinal photography and ophthalmoscopy has been recommended to increase sensitivity of screening for diabetic retinopathy.[1] This requires instant image availability so that the two modalities may complement one another. To date Polaroid photography has been the only means of ensuring instant image availability, but the image quality of Polaroid is inferior to that of 35 mm film. Retinal cameras are now being developed which use video/digital imaging techniques to produce an instant enlarged retinal image on a computer monitor screen. We set out to compare such an electronic imaging system with standard Polaroid retinal photography.

Patients and methods

Consecutive diabetic patients who were having their eyes dilated for fundal assessment were invited to have the extra assessments of this study. The patients were attending one of four clinics at the time: the main hospital diabetic clinic (59 patients); the hospital annual review test clinic (21 patients); the diabetic eye screening-only clinic (13 patients); and the ophthalmology clinic (14 patients). Two hundred and thirteen eyes from 107 diabetic patients were each photographed twice (in both cases using a standard 45° field, including the macula and optic disc) in random order through dilated pupils by two methods:

1. An electronic imaging system attached to a Canon CR5 45NM retinal camera which produced a still video image via a Sony OXC 930 3 Chip Camera which was used for the study although the still video images could be digitized using a computer video image grabber.
2. Standard Polaroid photography using a Canon CR4 45NM retinal camera.

Each Polaroid and each electronic image was examined by an experienced observer (REJR). The observer was blind to all details about the patient and electronic images were looked at separately in random order with the observer blind to the findings on the other modality. As the aim was only to compare the imaging systems,

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the results from ophthalmoscopy were not available to the observer.

The diagnosis of diabetic retinopathy was made if retinopathy were detected on either the electronic image, the Polaroid, or both. Each image was categorized as either 'no retinopathy', 'background diabetic retinopathy', or 'sight-threatening diabetic retinopathy'. For the purposes of this study, sight-threatening diabetic retinopathy was defined as diabetic retinopathy requiring referral to an ophthalmologist according to standard European criteria.[2] The criteria are shown in Table 1.

Brightness of the Photographic Flash

The brightness of the photographic flash required to produce an electronic image is less than that required to produce a Polaroid image. In order to assess the extent to which patients could detect the difference, patients were asked, after photography by each system, to place a mark on a linear analogue scale to reflect their assessment of the brightness of the flash. The position of the mark on the scale was measured to give a score in the range 0 cm (not very bright) to 10 cm (very painfully bright). The scores obtained for the two imaging systems were compared using a paired Student's *t*-test.

Results

Diabetic retinopathy was present on at least one of the images in 58 of the 213 eyes; 55/58 (95 %) were detected on electronic imaging and only 49/58 (84 %) on Polaroid. In 24 eyes the retinopathy was classed as background diabetic retinopathy and in 34 eyes as requiring ophthalmologist referral according to the standard European criteria.[2] Of those requiring referral, 34/34 (100 %) were detected on electronic imaging compared with only 24/34 (71 %) on Polaroid. Side by side comparisons showed electronic imaging to be superior to Polaroid for lesion detection. Figures 1–4 show examples of images of the same eyes produced by the two systems. There is inevitably some loss of image quality through the process of reproduction, but nevertheless the superiority of electronic imaging over polaroid is well shown.

The linear analogue score (mean ± SEM) for the brightness of the electronic imaging photographic flash experienced by the patients (5.9 ± 0.25 cm) was significantly less than that for the Polaroid equivalent (8.1 ± 0.17

Table 1. European criteria for referral to an ophthalmologist[2]

Sight-threatening retinopathy requiring immediate referral

- Proliferative retinopathy:
  - new vessels on the optic disc or elsewhere in the retina
  - pre-retinal haemorrhage
  - fibrous tissue
- Advanced diabetic eye disease:
  - vitreous haemorrhage
  - fibrous tissue
  - recent retinal detachment
  - rubeosis iridis

Lesions to be referred for assessment as soon as possible by an ophthalmologist

- Pre-proliferative retinopathy:
  - venous irregularities (beading, reduplication, loops)
  - multiple haemorrhages
  - multiple cotton wool spots
  - intra-retinal microvascular abnormalities (IRMA)
- Non-proliferative retinopathy with macular involvement:
  - reduced visual acuity not corrected by pinhole (suggestive of macular oedema)
  - haemorrhages and/or hard exudates within one disc diameter, of the macula, with or without visual loss
- Non-proliferative retinopathy without macular involvement:
  - large circinate or plaque hard exudates within the major temporal vascular arcades
- Any other findings that the observer cannot interpret with reasonable certainty.

Lesions not indicative of imminent development of sight-threatening retinopathy and not requiring immediate specialist assessment but follow-up screening in 6–12 months

- Non-proliferative retinopathy:
  - cotton wool spots in small numbers not associated with pre-proliferative lesions
  - occasional haemorrhages and/or microaneurysms (red 'dots and blots') and hard exudates not within one disc diameter of the macular area
  - Drusen may sometimes be confused with hard exudates; if not associated with other signs of age-related macular degeneration, they are not considered important

cm; $p < 0.0001$) and many patients remarked on the improvement in the comfort of the examination by the electronic imaging camera.

Discussion

Diabetic retinopathy is the major cause of blindness in the working age population in industrialized countries.[3,4] This blindness is potentially preventable in that if sight-threatening retinopathy can be detected in time, laser treatment can greatly reduce the progression to blindness.[5] Since early studies demonstrating its advantages over ophthalmoscopy,[6,7] retinal photography has become widely established as a means of screening for diabetic retinopathy. The twelve centre mobile camera screening study demonstrated that the incidence of sight-threatening retinopathy could be cheaply reduced using this form of screening.[8] In that study, Polaroid film was used in some centres because of its instant availability and 35 mm film in others because of the increased image quality and lower cost. Our study would suggest that electronic imaging may bring together the advantages of both.

The high rate of diabetic retinopathy requiring referral found in our study was because the study group was enriched by patients already attending an ophthalmologist. The superiority of image quality with electronic imaging compared to Polaroid illustrated in Figures 1–4 was found for all patients photographed. This superiority in image quality translates into superior lesion detection leading to increased sensitivity for detection of patients requiring referral to an ophthalmologist according to standard European criteria.[2] Previous studies have demonstrated that non-mydriatic Polaroid photography and mydriatic ophthalmoscopy may each miss sight-threatening retinopathy detected by the other.[9] It has therefore been argued[1] that ideally diabetic retinopathy screening should involve both photography and ophthalmoscopy and that, as photograph quality with the so-called non-mydriatic cameras increases substantially if the pupils are dilated,[10,11] pupils should be dilated for both.[1] Recent studies support this notion.[12,13] The results of the current study raise the possibility that lesion detection with the new method of imaging is so great that direct ophthalmoscopy becomes redundant. However with single 45° field photography, there will always be rare cases of only simple background retinopathy on the standard 45° field but serious lesions (e.g. new vessels[14]) beyond the reach of the photograph. There will therefore continue to be an argument for either also undertaking ophthalmoscopy or undertaking photography using two[2] or three fields[15] per eye.

It is likely that the image quality with electronic imaging is similar to that of 35 mm photographic film . The electronic image however is available instantaneously so that ophthalmoscopy may be undertaken immediately while the patient is still present with eyes dilated. The ophthalmoscopy may be guided by the findings on the electronic image. Furthermore, the instant availability of the electronic image confers the advantage that if there is any problem with quality this is detected immediately so that a further photograph may be taken.

The cost of hardware and software to attach to the camera to facilitate electronic imaging is not insubstantial. Indeed, using the Canon CR5 45NM, the cost of the extras for electronic imaging approximately doubles the cost, compared to simply buying the same camera with Polaroid attachment. Currently the UK costs are approximately £16 000 for Canon CR5 45NM with Polaroid attachment (earlier versions of the Polaroid cameras can be purchased more cheaply), and £32 000 for Canon CR5 45NM with electronic imaging attachments. As with most computer-based technologies, it is to be hoped that these costs will come down. After the initial outlay on hardware and software, the electronic image itself is effectively without cost whereas the ongoing film cost for Polaroid is about £1 per eye, for 35 mm slide about £0.33 per eye (for materials: nearly £1.50 per eye when labour costs for developing, mounting

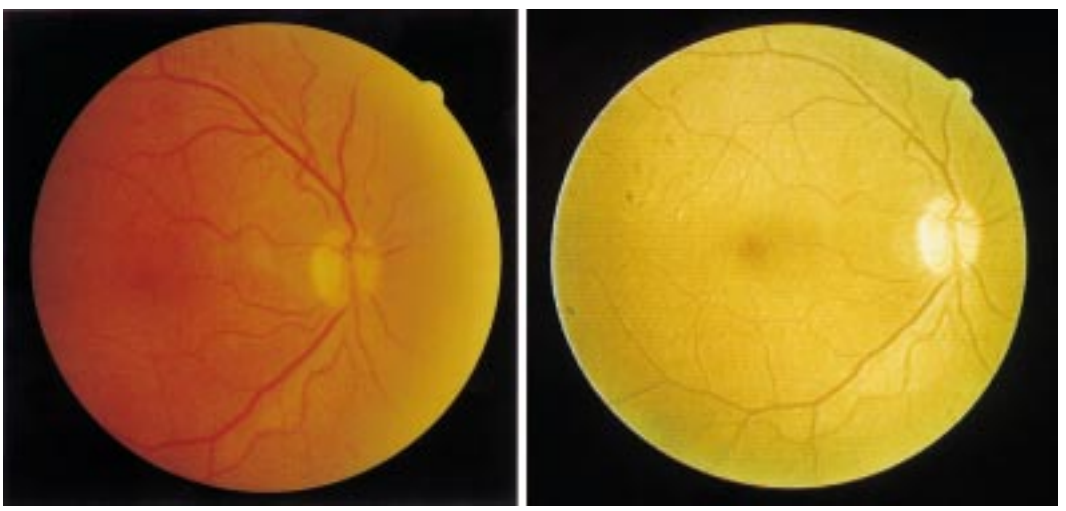

Figure 1. Though the Polaroid image (left) was reported as 'no diabetic retinopathy', moderate background was reported on the electronic image (right), including dot haemorrhages close to the macula

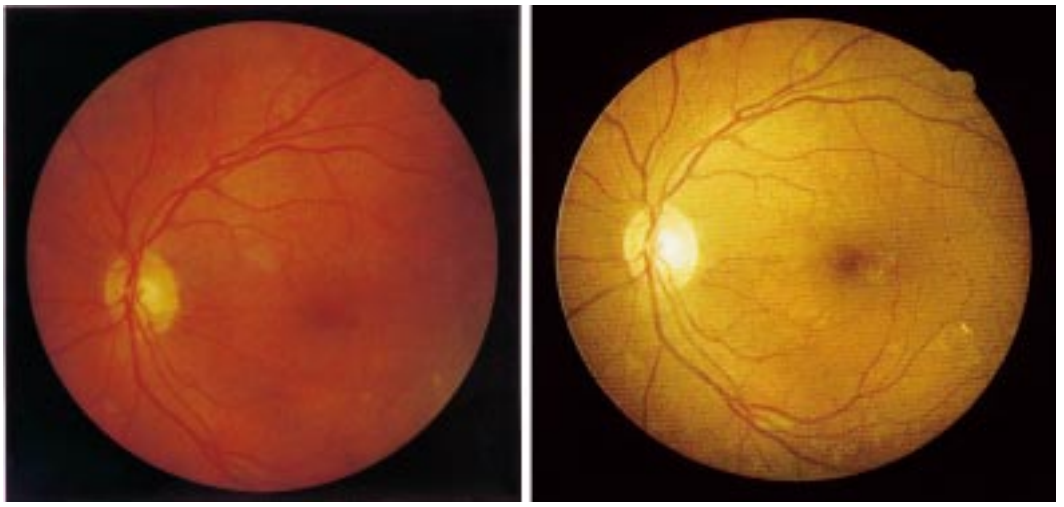

Figure 2. Though background diabetic retinopathy was diagnosed from the Polaroid (left), the presence of hard exudates within one disc diameter of the macula was only fully appreciated on the electronic image (right)

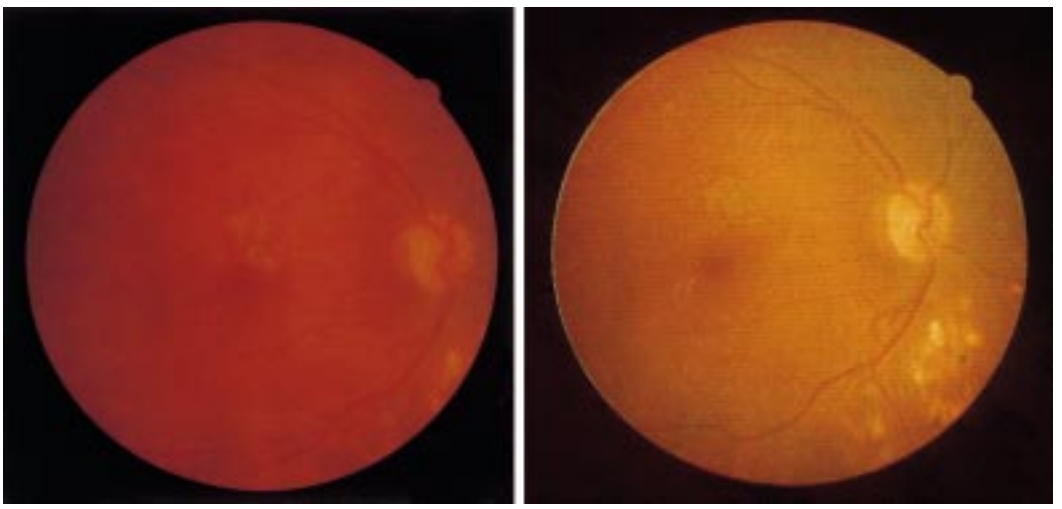

Figure 3. In this patient with cataract, the presence of hard exudates within one disc diameter of the macula was appreciated on the electronic image (right) but not the Polaroid (left)

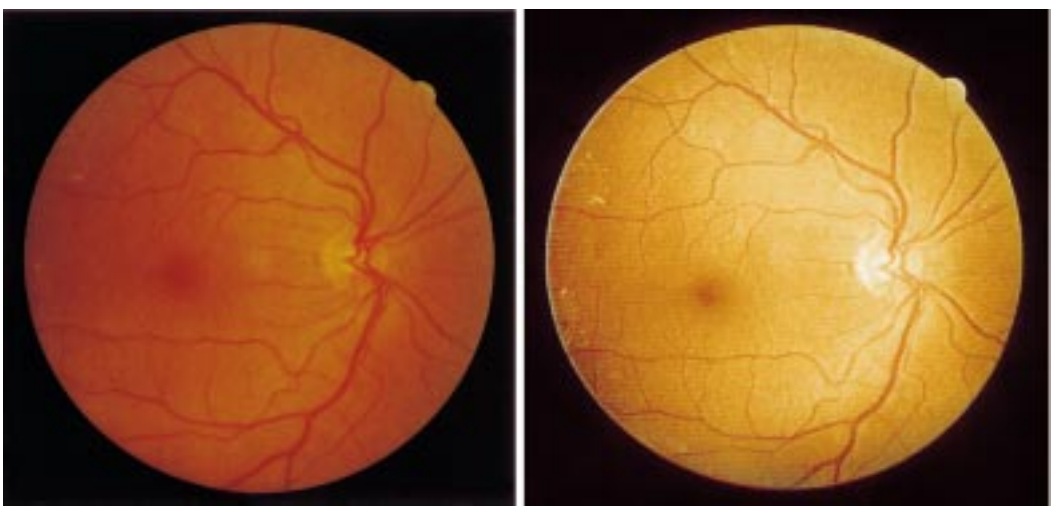

Figure 4. Though background diabetic retinopathy was noted on the Polaroid (left), the presence of circinate formations of hard exudates in the major temporal vascular arcade was only appreciated when the electronic image (right) was viewed

and labelling in a hospital medical illustration department are taken into consideration) and for 35 mm print about £0.4 per eye (for materials: nearly £2.00 per eye when labour costs for sending off to and paying for professional processing of the film, and labelling of pictures on return, are taken into consideration).

There are also other potential advantages for electronic imaging. The images can be readily stored on and retrieved from the increasingly cheap and capacious computer storage media. They could readily be attached to the patient's electronic clinical record on a computerized diabetes register/database. The images lend themselves to the possibility of image enhancement and analysis using image analysis software. There is potential for developing software in the future capable of detecting and reporting lesions. There is also the possibility of electronic transfer of images to the ophthalmologist, for patients requiring referral, to help with prioritization decisions and even obtain his/her opinion. Electronic transfer of images to the GP is possible. Images could be printed for the patient's case-notes and for the GP, with the report of the screening, although whether printouts of sufficient quality can be produced cheaply has not been shown.

We conclude that electronic imaging systems represent a major potential advance for the improvement of diabetic retinopathy screening.

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